CHARACTERIZATION OF THE MECHANICAL BEHAVIOUR OF MATERIALS IN THE TENSILE TEST: EXPERIMENTS AND SIMULATION

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ABSTRACT

The tensile test is an important standard engineering procedure useful to characterize some relevant elastic and plastic variables related to the mechanical behaviour of materials. Due to the non-uniform stress and strain distributions existing at the neck for high levels of axial deformation, it has been long recognised that significant changes in the geometric configuration of the specimen have to be considered in order to properly describe the material response during the whole deformation process up to the fracture stage. Although in many engineering applications the design of structural parts is restricted to the elastic response of the materials involved, the knowledge of their behaviour beyond the elastic limit is relevant since plastic effects with usually large deformations take place in the previous manufacturing procedures such as forming, forging, etc.

Although the diffused necking process in the tensile test has been extensively studied, it is a well-known fact that the description of the stress distribution at the neck is a difficult task that depends not only on the geometry of the specimen (i.e., cylindrical or sheet samples) but also on the axial deformation level (characteristic of each material) at which the uniformity in strains and stresses is lost.

The aim of this paper is to present an experimental analysis and a numerical simulation of the mechanical behaviour during the tensile test experienced by both cylindrical and sheet specimens of different materials: structural steels, aeronautical aluminium alloys and pure copper. To this end, the experimental procedure undertaken to characterize some specific features of the material response as well as the details considered in the derivation of the parameters involved in the assumed exponential plastic hardening law are given. Moreover, the governing equations together with the constitutive model proposed to simulate the deformation process that takes place during the test are also presented. This large strain isotropic elastoplasticity-based formulation includes the definitions of a specific free energy function and plastic evolution equations which are the basis to derive the stress-strain relationship and a thermodynamically consistent expression for the internal dissipation. Some aspects of the corresponding finite element model are briefly described. Finally, the results obtained with the proposed formulation are validated with the corresponding experimental measurements. Aside from the engineering stress-strain curve, different results at the section undergoing extreme necking are specifically analysed: ratio of current to initial diameter in terms of the elongation and both load and mean true axial stress versus logarithmic strain.

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